

An Exploration of the Potential for 'Opti-Acoustic' Seabed Classification

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LONG-TERM GOALS

Seabed classification is the organization of the seafloor and shallow subsurface sediment into classes based on defined characteristics (Collins, 1996). Optical and acoustical data processing are two powerful remote sensing techniques for sea floor classification. Our research goal is to explore the potential for the fusion of these two data sets to extend classification capabilities beyond traditional methods.

OBJECTIVES

Specific objectives are (1) to evaluate the utility of optical and acoustical mapping for shallow water bottom mapping using feature extraction and statistical processing methods; and (2) to evaluate the utility of integrated "opti-acoustical" processing in relation to individual optical and acoustical methods. This work represents a research collaboration between the University of Miami and Quester Tangent Corporation (QTC).

APPROACH

Benthic habitat maps have traditionally been constructed from interpretation of optical imagery. This approach works well for broad habitat types in optically shallow water, but the accuracy of optically-derived seabed classifications degrades significantly in deep or turbid water and when using detailed classification schemes (e.g. Mumby et al. 1997). The approach explored in this project uses acoustics to obtain additional seabed information, thereby potentially increasing classification accuracy and/or extending benthic habitat classification into optically deep water.

The justification for this approach is based on the fact that optical and acoustic remote sensing systems respond to different physical properties of the seabed. Information contained within optic and acoustic signals should thus be complementary. Optical classifications are based on spectra of reflected light, which are controlled by the surface of the seabed and the water column. Acoustic classifications are based on the shape of acoustic pulses reflected from the seabed, which, at the frequencies used, penetrate the bottom to a greater depth than electromagnetic radiation. Three factors dominate the shape of the reflected acoustic pulse: acoustic impedance discontinuity at the water/bottom interface,

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14. ABSTRACT Seabed classification is the organization of the seafloor and shallow subsurface sediment into classes based on defined characteristics (Collins, 1996). Optical and acoustical data processing are two powerful remote sensing techniques for sea floor classification. Our research goal is to explore the potential for the fusion of these two data sets to extend classification capabilities beyond traditional methods.					
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inhomogeneities within the volume insonified by the pulse, and backscatter from the bottom surface (Bornhold et al., 1999; Preston et al., 1999).

In our approach, three data sets are acquired simultaneously from a small vessel. An acoustic data set is acquired with a Quester Tangent Corporation (QTC) “QTCView” system V. An optical data set is acquired with a Satlantic hyperspectral tethered spectral radiometer buoy (HTSRB) towed behind the boat. Finally a video data set is acquired with a camera mounted to the pole supporting the acoustic transducer. The video camera is set on time-lapse mode, acquiring 2 sec every 30 sec.

Processing includes quality control of acoustic data to remove echoes with incorrect bottom picks or low signal to noise ratio; water column correction of the HTSRB data to convert the ratio of upwelling radiance over downwelling irradiance to estimated bottom reflectance (Louchard et al, submitted, Reid, this volume); and extraction of a single frame from each two second video clip. All data sets are georeferenced using WAAS-enabled GPS.

An operator evaluates each video scene and classifies it according to bottom type. These bottom types are grouped into the three major classes (sand/seagrass/ hardbottom), which are typically used in optical classification of tropical coastal seabeds (e.g. Florida Marine Research Institute, 1998), and a variety of subclasses. The acoustic and HTSRB data are classified using QTC Impact software, which uses a series of algorithms to derive 166 descriptors for each feature. Some of these features are based on echo shape, and others on spectral characteristics. (Collins and Lacroix, 1997). The acoustic and HTSRB data sets are classified separately to evaluate objective (1), while they are concatenated and then classified together as a single signal to evaluate objective (2).

WORK COMPLETED

Simultaneous video, HTSRB, and acoustic data sets were collected during June 2001 in the vicinity of Lee Stocking Island, Bahamas (LSI). The video data have been processed and classified (Figure 1a). The HTSRB data have been corrected for water column attenuation to retrieve estimated bottom reflectance and clustered using QTC Impact software (Louchard et al. submitted; Reid, this volume). The acoustic data have been classified using both supervised (Figure 1b) and unsupervised (Figure 2) modes of QTC Impact.

SCUBA divers surveyed over 40 sites near LSI during June 2002 in order to ground truth classifications based on 2001 survey. Ground truth efforts were in the Adderly Cut area, just north of LSI. The divers probed sediment depth, collected sediment cores, made roughness measurements, and described and photographed the bottom cover at each site. The cores are in the process of being analyzed to determine grain size and index properties; the other parameters (probe resistance and visual descriptions) are already contributing to an understanding of acoustic diversity (see RESULTS, below).

A second survey was conducted during October 2001 near the Atlantic Undersea Testing and Evaluation Center (AUTECE) base on Andros Island, Bahamas. The video data for this survey have been processed and classified, and the acoustic data have been processed to generate preliminary seabed classification maps. Due to limited space in this report and a more comprehensive ground truth data set at LSI, only results for the LSI survey will be presented here.

Analyses to date have focused on comparison of habitat maps generated from acoustic data versus those derived from optical data. None of the data have yet been submitted to a public archive, as data interpretation is ongoing.

RESULTS

Video classification produced benthic habitat maps with three major bottom-type classes and a variety of subclasses. The major classes (sand/seagrass/hardbottom) are typical for optical classifications of tropical seabeds (e.g. Florida Marine Research Institute, 1998; Mumby et al., 1997). The distribution of major classes (Figure 1a) shows good spatial continuity and conforms well to previous work in the area (Gonzalez and Eberli 1997; Louchard et al, in press).

HTSRB classification has a high correlation with the video classification after applying a water column correction to convert Lu/Ed to bottom reflectance (Louchard et al submitted, Reid, this volume). Relative to the video classification, the overall accuracy of the HTSRB classification is 81% for the three major classes and 70% for five subclasses. This level of performance is consistent with previous efforts to classify tropical coastal seabeds using optical data (e.g. Mumby et al., 1997).

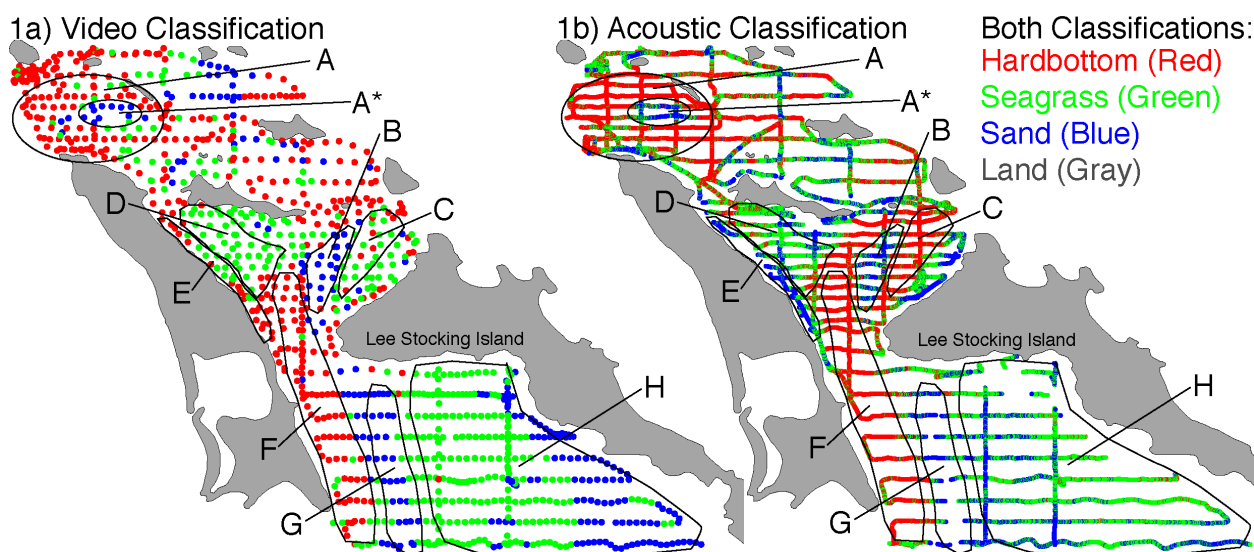


Figure 1: Video (1a) and supervised acoustic (1b) seabed classifications in the vicinity of Lee Stocking Island. Several major features can be identified in both data sets-- for example ooid shoals in areas A,B,G, seagrass area D and the hardbottom regions A and F. Areas of disagreement, such as sparse seagrass/sand in area H, nearshore sand/hardbottom in area E, and deep hardbottom/seagrass in area C are confined to specific continuous regions and therefore are unlikely to be random errors (see text for explanation).*

Acoustic classification of benthic habitats shows general similarities with video and optical classification and but also exhibits some discrepancies. In areas A,A*,B,D,F,G of Figure 1, there is good correlation between the supervised acoustic and video classifications. In areas C,E, and H of

Figure 1, correlation between supervised acoustic and video classification is poor. The fact that these areas of disagreement are concentrated in discrete patches suggests that they are not random errors, but rather have a physical explanation. The habitat assessment performed by SCUBA divers during June 2002 in the Adderly Cut area begins to explain the discrepancies.

Diver assessments indicate that bottom types in Adderly Cut are more complex than can be accommodated by a simple sand/seagrass/hardbottom classification scheme. For example, Area C, Figure 1, is a rubble-covered hardbottom interspersed with seagrass-stabilized sand dunes over 1 m high. Thus, both video (mainly seagrass) and supervised acoustic (mainly hardbottom) classifications are partly correct. In reality, however, the co-occurrence of sand, seagrass, and hardbottom within a small area comprises a distinct habitat, which does not fit within the simple three class framework. This suggests that inherent acoustic diversity within a survey area must be determined before an appropriate supervised classification scheme can be chosen. Determining inherent diversity is accomplished through unsupervised classification (Fig. 2).

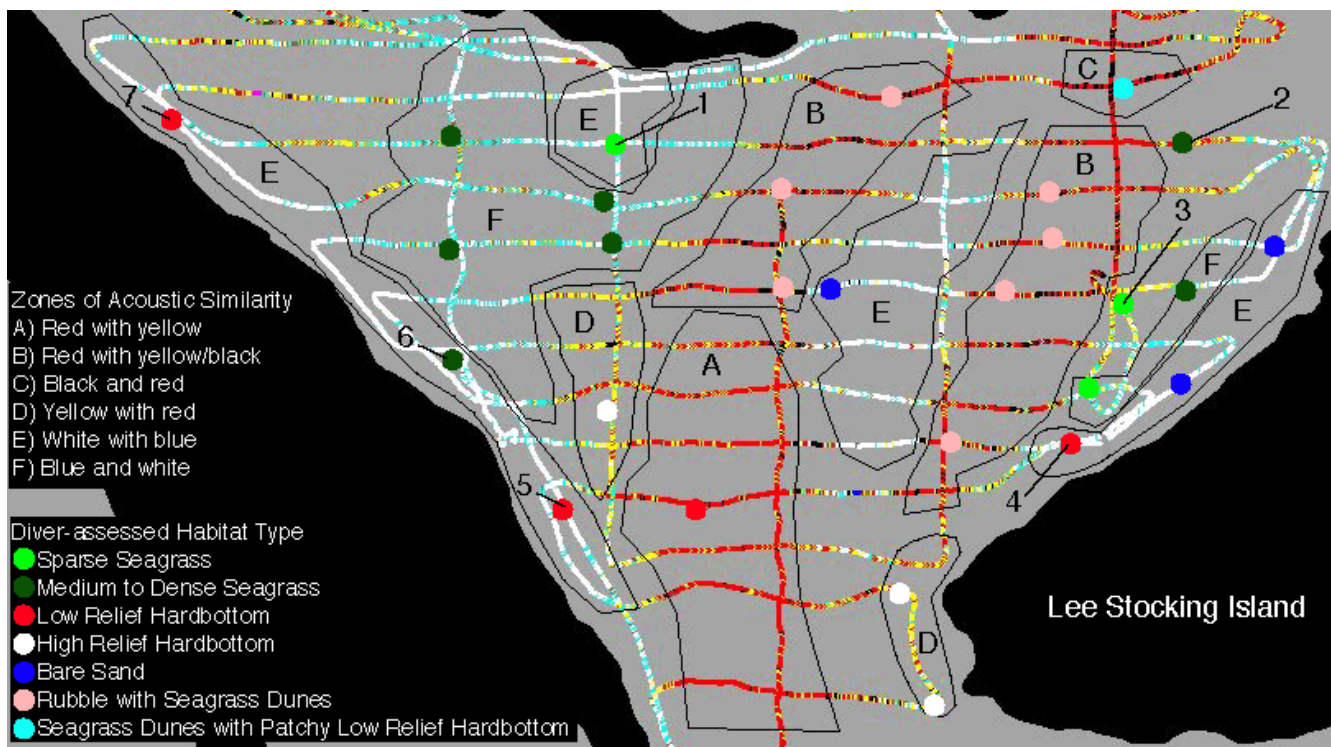


Figure 2: Unsupervised acoustic classification of the Adderly Cut area. Six distinct acoustic classes, represented by colors of the track lines, were identified with the QTC Impact clustering software.

These six classes are grouped into ‘Zones of Acoustic Similarity’ (A-F), with equivalent color combinations. Dive sites are shown as large dots colored according to diver-assessed habitat type. In general, Zones of Acoustic Similarity correspond to unique habitat types (see Table 1); discrepancies at Sites 1-7 are discussed in the text.

Unsupervised classification of acoustic data in the Adderly Cut area defined six individual acoustic classes. These classes are represented simply as colors (red, yellow, black, white, blue, brown) plotted along the track lines in Figure 2, since the physical significance of each class is not known. Zones of

Acoustic Similarity, as defined by subjective grouping of color patterns, are outlined in black and designated by letters (A, B etc). Color combinations comprising each ‘Similarity Zone’ are described in the legend using the convention that ‘x *with* y’ signifies dominant x with minor y, whereas ‘x *and* y’ signifies similar proportions of x and y. Dive sites are plotted as solid circles colored according to the seabed descriptions in the legend.

In most cases, dive sites with similar seabed descriptions fall within equivalent ‘Acoustic Similarity Zones’ (Table 1); exceptions are Sites 1-7. Site 1 was identified by divers as sparse seagrass, but falls within Acoustic Zone E, which is typically a zone of bare sediment. This discrepancy is reasonable, as sparse seagrass is mostly bare sediment; in addition, resistance to penetration at Site 1 was very low, as it was at all bare sediment sites. Divers identified Sites 2 and 3 as dense and sparse seagrass, respectively. These points do not, however fall within Zone F, the (blue and white) zone typically associated with sea grass; instead track lines near Sites 2 and 3 are red/yellow, colors typically associated with hardbottoms. This discrepancy might be explained by penetration resistance, which was much higher at Sites 2 and 3 than at any other seagrass sites. Finally, Sites 4-7, identified by divers as seagrass and hardbottom, fall within Acoustic Zone E, typically associated with bare sediment. These sites are located in less than 2.5 meters of water, suggesting that current classification may not be valid in water depths less than 3 meters. Additional data processing is being conducted to investigate potential noise problems in shallow water signals.

Table 1: Correspondence between Zones of Acoustic Similarity and diver-based seabed descriptions.

Acoustic Zone	<i>Diver Description</i>	Acoustic Zone	<i>Diver Description</i>
A	Low Relief Hardbottom	D	High Relief Hardbottom
B	Rubble with Seagrass Dunes	E	Bare Sand
C	Seagrass Dunes with Low Relief Hardbottom	F	Seagrass

IMPACT/APPLICATIONS

Results to date indicate that acoustic diversity is distinct from optical diversity, offering the potential to provide additional, complementary information for benthic classification. In addition, our findings indicate that benthic habitats do not necessarily correspond to individual acoustic classes, but may instead be defined by ‘Zones of Acoustic Similarity’, comprising combinations of individual classes. Future efforts to merge optical and acoustic data sets are, therefore, likely to lead to identification of specific benthic parameters, including physical properties that cannot be differentiated using optical and acoustic signatures individually. By using optical and acoustical technologies in tandem within the photic zone, classification schemes may be extended beyond water depths where significant spectral reflectance can be detected by optical sensors on airborne or satellite platforms. Results will be important for military, management and fisheries applications requiring benthic habitat maps.

TRANSITIONS

We are working with Dr. A.M. Eklund, National Marine Fisheries Service, Virginia Key, FL, to use acoustic seabed classification methods for mapping deep water fish habitats in the Florida Keys. In addition, Dr. P. Kramer is using depth/classification information from our Andros survey for validating seabed maps derived from IKONOS imagery.

RELATED PROJECTS

Our research on opti-acoustic seabed classification is closely related to the CoBOP program. Collaboration with Dr. C. Mobley will generate software to correct PHILLS data for water column attenuation. This will enable analysis of PHILLS data using techniques tuned to spectral shape, as used in this study. In addition, the bathymetry map for shallow water areas in the LSI vicinity, generated during the opti-acoustic surveys, is being used by NRL (R. Leathers and colleagues) for PHILLS algorithm development.

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- Reid, R.P. 2002. Composition, Texture and Diagenesis of Carbonate Sediments: Effects on Benthic Optical Properties. Award Number: N000149710010, this volume.

PUBLICATIONS

Peer-reviewed publications acknowledging support from Award Number: N000140110671:

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Abstracts presented at national meetings based on results from Award Number: N000140110671:

Gleason, A.C.R., Louchard, E.M, Reid, R.P., Collins, W.T. (2002) Initial results of seabed classification using fused hyperspectral and acoustic data. AGU Ocean Sciences meeting, Honolulu, HI, February 10-15, 2002.

Gleason, A.C.R., Louchard, E.M, Reid, R.P., Collins, W.T. (2002) 'Opti-acoustic' seabed classification Part 1: concepts and acoustic classification. Seventh International Conference on Remote Sensing for Marine and Coastal Environments. Miami, FL, May 20-22, 2002.

Louchard, E.M, Gleason, A.C.R., Reid, R.P., Collins, W.T., Mobley, C.D. (2002) Opti-acoustic classification part 2. Classification of benthic habitats using optical data: a method for removing effects of water column attenuation. Seventh International Conference on Remote Sensing for Marine and Coastal Environments. Miami, FL, May 20-22, 2002.

Louchard, E.M, Gleason, A.C.R., Reid, R.P., Collins, W.T., Mobley, C.D. (2002) Shape Analysis of Hyperspectral Bottom Reflectance Data: Application to Remote Sensing Classification of Benthic Habitats. AGU Ocean Sciences meeting, Honolulu, HI, February 10-15, 2002.

Gleason, A.C.R., A.-M. Eklund, R.P. Reid, D.E. Harper, D.B. McClellan, J. Schull (2002) Integration of acoustic seabed classification and fish census data for determining appropriate boundaries of marine protected areas. Symposium on Effects of Fishing Activities on Benthic Habitats: Linking Geology, Biology, Socioeconomics, and Management, Tampa, FL, November 12-14, 2002